the Fleet a great Quantity of Vinegar to waſh the Decks of the Ships with, in order avoid Infection.

Theſe are the Improvements of my Preparation of the *Volatile Spirit of Sulphur*; to which more might be added about its Uſes, as a *Menſtruum*, and particularly with regard to Pharmacy, as in making the *Elixir Vitrioli*, &c. acidulating Juleps; and anſwering all the principal Ends of an Acid; but having a Mind to finiſh this Eſſay, I ſubmit it to the candid, and judicious Reader, deſiring of him this Favour, that he would endeavour to ſet me right in any Thing, in which, he thinks, I am miſtaken.

FINIS.

PATENT OFFICE LIBRARY.

BRITISH LIBRARY

17231 1143/A -/10

NEW
EXPERIMENTS
AND
OBSERVATIONS
CONCERNING
ELECTRICITY.

In FOUR PAPERS;
Read at ſeveral Meetings of the ROYAL SOCIETY,
in the Year 1759.

By ROBERT SYMMER, *Eſq*; *F. R. S.*

WITH
A Letter from JOHN MITCHELL, *M. D. F. R. S.*
To THOMAS BIRCH, *D. D. Secretary to the Royal Society,*
relating to ſome of thoſe Experiments.

LONDON:
Printed by L. DAVIS and C. REYMERS, Printers of the R. S.
M.DCC.LX.

1600/1350.

COMMISSIONERS OF PATENTS FOR INVENTIONS

BRITISH MUSEUM
31 DEC 72

TO

THE RIGHT HONOURABLE

FRANCIS, Earl *Brooke*, Earl of *Warwick*,
Lord *Brooke*, Baron *Brooke* of *Beauchamps-Court*, in the County of *Warwick*, and
Knight of the moſt Antient Order of the
Thiſtle;

THESE PAPERS,

In Teſtimony of the ſincereſt Gratitude, and moſt
Reſpectful Affection,

Are humbly Inſcribed

BY

His LORDSHIP's moſt obliged,

and moſt obedient Servant,

ROBERT SYMMER.

NEW EXPERIMENTS AND OBSERVATIONS CONCERNING ELECTRICITY.

PATENT OFFICE LIBRARY

PAPER I.

Of the Electricity of the human Body, and the Animal Subſtances, Silk and Wool.

Read Feb. 1. 1759. I had for ſome time obſerved, that upon pulling off my ſtockings at night, they frequently made a crackling or ſnapping noiſe; and in the dark I could perceive them to emit ſparks of fire. I made no doubt but that this proceeded from a principle of electricity; and I was confirmed in this opinion, by obſerving that, in weather favourable for electrical experiments, thoſe appearances were more remarkable than at other times. I mentioned this obſervation to ſeveral of my friends, and ſome of them told me, they likewiſe had often perceived the ſnapping, and the emiſſion of fire from their ſtockings upon pulling them off, eſpecially in the winter nights: but I could not hear of any body that had taken this phenomenon into conſideration in a philoſophical way. For my own part, I could not but think that ſo ſtriking an appearance, one that ſeems to have an immediate connexion with the human body, or is at leaſt as much about us as the cloaths we wear, and is obvious to the perception of our ſenſes, merited not only a philoſophical attention, but the ſtricteſt inquiry poſſible. I was the more induced to ſuch an inquiry, as it ſeemed to me to open a new path for proceeding in electrical reſearches, and might perhaps throw new light on the great and ſurpriſing diſcoveries already made in that branch of natural philoſophy. The ſimplicity of the apparatus, and the great facility in making the proper experiments, putting it in my power to begin and carry on my enquiry at pleaſure, I entered upon ſomewhat of a regular courſe of obſervations about the beginning of November laſt; and ſince that time have purſued it as cloſely as my leiſure, and the weather, which has been far from favourable for electrical experiments, would permit. It is the purpoſe of this, and of thoſe papers that may follow, to lay before the Royal Society an account of the experiments and obſervations I have already made, or may hereafter be able to make, in the progreſs of this inquiry.

My firſt endeavour was to diſcover what ſort of ſtockings was moſt proper to produce electricity.

In order to determine this, I tried ſingle ſtockings of different kinds, *viz.* thread, cotton, ſilk, and worſted, putting them on, and wearing them ſome time. On pulling them off, I could perceive nothing of electricity in the thread or cotton, and no remarkable degree of it in the ſilk and worſted.

When I ſay *no remarkable degree of it*, it may be proper to be a little more explicit. I muſt therefore obſerve, that ſilk and worſted, being in themſelves electric, are both of them, eſpecially ſilk, extremely ſuſceptible of electricity. I have ſometimes obſerved, particularly when the weather was favourable, that ſilk, when but barely handled, nay, when but ſimply touched, has become electrical where it had been handled or touched, as appeared by its attracting little light balls ſuſpended by threads. It cannot therefore be ſuppoſed that ſilk or worſted ſtockings can be put upon the leg, without being excited to a ſenſible degree of electricity. And thence it is, that when taken off they are ſometimes perceived to ſnap, though worn ſingle. But whatever electricity the ſingle ſtocking acquires by friction or otherwiſe, it immediately loſes upon being ſeparated from the leg: if any electric virtue remains, it is no more than what belongs to it as an electric ſubſtance ceaſing to be excited; and it is in ſo ſmall a degree, as in the preſent caſe not to merit attention. In general, when I ſpeak of the electricity in queſtion, I mean ſuch a power of electricity as is obvious, and perceptible to the ſenſes; ſo that the ſtocking, after being taken off, ſhould appear more or leſs inflated; throw out an electrical wind to be felt by the bare leg; attract or repel another ſtocking viſibly; and, upon the touch, ſnap, and emit, or receive electrical fire.

After making the experiment above-mentioned with ſingle ſtockings, I proceeded to try the effect of two ſtockings upon one leg. This I did with two of thread, cotton, worſted, and ſilk ſucceſſively; but this produced no electrical appearance more than before. I then combined them one with another, and, running through all the different changes, I found that none of thoſe I then made uſe of exhibited viſible proofs of electricity, but the ſilk and worſted together; and there, indeed, the electric power appeared remarkably ſtrong. It ſeemed to be a matter of indifference whether the ſilk or the worſted was uppermoſt, the combination of the two was what I judged to be eſſential; and happening at that time to wear ſilk ſtockings with thin worſted under them, I kept to the uſe of theſe, and found it a convenient circumſtance in the courſe of my experiments.

As ſome may have the curioſity to examine the obſervations I preſent them with, by experiments of their own making; before I proceed further, I ſhall furniſh them with a few remarks, which may enable them to make their experiments with more eaſe and certainty, than if they ſet out unacquainted with ſome circumſtances, which I have learnt from experience.

One of the firſt things to be attended to, is the weather, which has an influence on all electrical experiments, but upon none more than thoſe which relate to this branch of electricity. The moſt favourable weather is that which is dry and clear, and, if a little froſty, ſo much the better. In general, when the quickſilver in the barometer riſes, and the fire burns remarkably briſk and clear, we may expect a con-

PATENT OFFICE LIBRARY

26

conſiderable appearance of electricity: at other times, it is better not to attempt the experiment.

When the weather is favourable, it is not neceſſary to wear the ſtockings all day: That, indeed, raiſes the electrical power to the higheſt degree; yet, provided they be dry, and made warm by the fire, before they are put upon the leg, their continuance upon it for a very ſhort time, prepares them ſufficiently for exhibiting viſible proofs of electricity. If this ſhould not anſwer upon the firſt trial, the operation may be repeated two or three times, to bring them into a proper diſpoſition to receive the electrical virtue; and this is no more than what is found to be ſometimes neceſſary with reſpect to glaſs globes and tubes, eſpecially when new. If the ſtockings have once acquired this diſpoſition, they retain it for the day, or until a change of weather, and the experiment may be repeated with ſucceſs as often as one pleaſes; for no ſooner are they diſcharged of their electricity, than they are ready to receive it anew; nay, if ſpeedily returned upon the leg, they catch it inſtantaneouſly, and may immediately be pulled off to exhibit a new exploſion: what is ſtill more ſurpriſing, they ſeem to gather force by the frequency of the repetition, and, to ſome certain degree, increaſe in electrical power, provided they be all along kept warm and dry, and that the leg continue warm.

Another circumſtance to be carefully attended to, is the manner in which they are to be taken off; for as to the putting of them on, it is a matter of indifference how that is performed. In taking them off, care muſt be had not to ſeparate them; for if that happens in pulling them off, all the electricity eſcapes.

The beſt way, is to put the hand between the leg and the ſtockings, and puſh them off together. Nothing more remains to be done, than to pull them aſunder; for upon that, they both of them exhibit a degree of electricity, which, when at the higheſt, is really ſurpriſing.

Before I conclude theſe occaſional remarks, it may not be improper to obſerve, that it is not abſolutely neceſſary that the ſtockings be applied to the bare leg; if a fine thread ſtocking ſeparate them from the leg, though left upon it when they are taken off, it does not much impair their electricity. But it is more convenient to uſe the hand inſtead of the leg. The inſertion of the hand into the ſtockings, is alone ſufficient, eſpecially in favourable weather, to communicate ſuch an electric power, as renders them capable of anſwering expectation, in ſuch experiments as I have had occaſion to make*.——I now return to my ſubject.

The opinion I had conceived, that the combination of ſilk and worſted was neceſſary for the production of electricity, ſeemed to meet with confirmation from all the experiments I made with the ſtockings I then wore. I was at that time in mourning, ſo that my ſilk ſtockings were black, and under them I conſtantly wore thin white worſted. About the latter end of November I went out of mourning, and of courſe changed the colour of my ſtockings. On the ſecond of December, having put on a pair of white ſilk above the worſted, after I had wore them ſome hours, I reſolved to amuſe myſelf with a few experiments. The weather was remarkably favourable, and I had reaſon to expect a fine appearance of electricity: but upon taking off my ſtockings, and pulling them aſunder, to my great aſtoniſhment, I found they diſcovered no ſigns of electrical power; as I held them in my hands they hung down collapſed, and did not more attract one another, than before they were put upon my leg. I repeated the experiment two or three times, but with no better ſucceſs. An event I ſo little expected, diſconcerted me much. I ſaw I was no longer to aſcribe electricity to the combination of ſilk and worſted; but I remained at a loſs to know to what I *ſhould* aſcribe it. At laſt, upon conſidering the circumſtances of this and other experiments, a conjecture occurred, that the electricity in queſtion might depend upon the nature of different colours. In order to determine this, I thought it faireſt to make the trial in the ſame ſubſtances. Accordingly I had recourſe to the following experiment.

---

* An improvement may perhaps be made upon this, by getting a piece of ſilk or worſted knit, or wove in the ſtocking loom, ſo that without being cut, it may be formed into the ſhape of long mittens or ſleeves, or rather into what we might call a ſilk or worſted tube. The reaſon why it ought to be knit, or wove in the ſtocking loom, is, that it may better embrace the hand or arm; and likewiſe, that it may be more retentive of electric virtue, which would eſcape more eaſily from a piece of ſilk or worſted wove in the common loom, and cut with a number of ends of threads expoſed, than from any thing formed in the faſhion of chain work, and conſiſting of one ſingle thread of ſilk or worſted.

I took a pair of white ſilk ſtockings, and having warmed them at the fire, put them both upon the ſame leg. After I had worn them about ten minutes, I took them off, and pulled them aſunder, but diſcovered no ſigns of electricity in either. I did the ſame with a pair of black ſilk, but to no other effect. I

then

then proceeded to the deciſive trial. I put a black and a white ſtocking upon my leg, and wore them likewiſe ten minutes. I waited with ſome impatience to ſee the ſucceſs of my experiment, and in return had the ſatisfaction of obſerving, upon their being pulled aſunder, that each of them had acquired a ſtronger degree of electricity than I had before ſeen: they were inflated ſo much, that each of them ſhewed the entire ſhape of the leg, and at the diſtance of a foot and a half they ruſhed to meet each other. I went through the ſame experiment with worſted ſtockings, and found that, as in ſilk, nothing but the combination of black and white produced electricity. As I had often experienced the power of electricity in the combination of black ſilk with white worſted ſtockings, there remained to try but that of white ſilk with black worſted, which anſwered as I expected, and ſeemed to complete the demonſtration.

A phenomenon ſo new, and of ſo curious a nature as this experiment preſented, could not but for ſome time engage my attention. I ſaw, that if this appearance did not ariſe from ſome accidental or collateral cauſe, correſpondent effects would follow, upon the combinations of the intermediate degrees of light and ſhade, between the extremes of white and black. I have had a particular attention to this in the experiments I have ſince had occaſion to make, and ſo far as I have yet been able to go, it appears to anſwer my expectation. Neverthleſs, as this is a matter that merits a more minute examination, we may hereafter take it up as an immediate object of inquiry; with a view to determine, if light and colours have, of their own nature, a relation with electricity, and in what that relation conſiſts.

In the mean while I ſhall purſue my principal deſign, which is to inveſtigate from experiments the nature of that electric virtue, with which the animal ſubſtances under conſideration appear to be endued. I have already made ſome progreſs, farther than what is contained in this paper; and I ſhall continue to follow the views that ſeem naturally to open to my inquiry. If I make any diſcoveries, or come at any concluſions that may merit the attention of the curious, they ſhall, together with the experiments on which they depend, be ſubmitted to the judgment of this learned Society.

PAPER II.

Of the Electricity of black and white Silk.

Read May 17, 1759.

IN my former paper, I gave the Society an account of ſome experiments, made with ſilk and worſted ſtockings; by which it appeared, that the remarkable degree of electricity they had acquired, by being put upon the leg, depended on their being of different colours, namely, black and white. I did not then, nor do I yet, take upon me to determine the cauſe of this phenomenon. Whether it be owing to light, which is the origin of colours; or only to the ingredients, which enter into the compoſition of the ſeveral dyes; or to thoſe conjunctly with the colours they produce: in any of theſe views the matter is curious, and equally merits a careful inquiry.—But I fear the ſolution of this, and of many other difficult queſtions concerning electricity, will depend upon the eſtabliſhment of a more perfect theory than we have yet attained to. Till we ſhall be ſo fortunate as to diſcover the nature and properties of the powers employed in theſe operations, we muſt be ſatisfied to purſue the path of experiment and obſervation, in queſt of thoſe, as firſt principles. This is the method I ſhall continue to follow; and having already ſhewn the manner of electrifying the black and the white ſtocking, it is now my purpoſe to give an account of the appearances and powers of that electricity ſo excited.

Having made a great number of experiments ſince I had the honour of preſenting my former paper to the Society, I have had an opportunity of obſerving, that the electricity produced between black and white ſilk, is ſtronger than that between ſilk and worſted of thoſe different colours, and a great deal ſtronger than that between worſted and worſted: the laſt is ſo weak, except in time of froſt, or when a ſharp north-eaſt wind blows, that tho' the effects are always of the ſame nature, yet they are ſometimes ſo languid as to be ſcarce perceptible. I ſhall therefore, and for the ſake of brevity, confine myſelf, in this paper, to what is obſerveable with regard to the electricity between black and white ſilk.

It is proper to mention another circumſtance: having found it troubleſome to electrify the ſtockings, by putting them as often on my leg as was requiſite in making experiments, I have quitted that method intirely; and ſatisfy myſelf with the degree of electricity which is excited in the ſtockings by drawing them upon the hand: and this is to be underſtood with regard to all the experiments and obſervations I may have occaſion to mention, unleſs when otherwiſe expreſſed. The electricity thus produced is not equally powerful with that which is excited by means of the leg; but it is nevertheleſs ſufficiently ſtrong to anſwer all the purpoſes in view; and it is attended with this advantage, that the ſtockings continue longer fit for theſe experiments: for, like other electrical aparatus's, they muſt be kept clean, and free from all extraneous matter; and are therefore moſt to be depended upon when new, or when newly waſhed.

To give a diſtinct account of the electricity of black and white ſilk, I ſhall trace it through its whole proceſs, beginning before the ſtockings of the different colours are put together.

After being a little air'd at the fire, when the black ſilk is drawn ſingle upon the hand, a crackling noiſe is heard; and in the dark, ſparks of fire may be perceived as paſſing between the hand and the ſtocking: while it is drawn backwards and forwards the crackling continues, and is moſt conſiderable upon the ſeparation of the ſtocking from the hand. Thus it appears, that black ſilk is highly ſuſceptible of electricity; that it is produced almoſt inſtantaneouſly, or at leaſt with very little friction; that moſt of it eſcapes, while the ſtocking is yet upon the hand; and that, upon the total ſeparation, very little remains. This is ſimilar to what happens with the glaſs tube, when the hand, after paſſing along it in one direction, repaſſes it in the other. But ſtill the electricity that the ſtocking retains, after it is ſeparated from the hand, is conſiderable enough to attract or repel little light bodies at the diſtance of one or two feet: ſome degree of inflation in the ſtocking is likewiſe perceiveable; and when a non-electric is brought near it, a crackling is heard, and in the dark ſparks may be ſeen. If two black ſtockings be drawn upon the hand at a time, the appearances are much the ſame as before; only that the ſtockings, when taken off and ſeparated, give ſmaller proofs of electricity, than if each of them had been ſingle upon the hand.

Having found it neceſſary, as I proceeded in my courſe of experiments, to fix upon ſome method of aſcertaining the principal appearances of electricity, and marking the degree of it, I had recourſe to the little pocket electrometer of Mr. Canton's contrivance, which is deſcribed in Vol. XLVIII. N°. 93. of the Tranſactions of this Society. When this inſtrument is ſupported by glaſs, it not only ſhews the attraction and repulſion, in general, of electrified bodies, which is one of the moſt eſſential properties of electricity, but it diſtinguiſhes between the poſitive and negative ſtate of electricity, according to the reciprocal attraction or repulſion of the little balls. By the terms *poſitive* and *negative*, I mean only to denote the oppoſition of the two different ſtates. The particular allotment of the one or the other term appears to me to be arbitrary; but that I may not differ unneceſſarily from others, I ſhall apply the word *poſitive* to that ſtate, in which a body is found to be, when electrified by the clear glaſs tube, rubbed by the hand; and the word *negative*, when electrified by the rough or opaque glaſs tube, of Mr. Canton's invention

PATENT OFFICE LIBRARY

vention (deſcribed in the Tranſaction mentioned above), when rubbed in the ſame manner, or by ſulphur or wax excited. In other words, when the body is in a ſtate of repulſion with the former of thoſe tubes, we ſay it is *poſitively* electrified, and *negatively* when in a ſtate of repulſion with the latter, or with ſulphur or wax.

Nothing appears to be more wonderful than this double ſtate: here electricity ſeems to counteract itſelf, the electrified body attracting in the one, what it would repel in the other caſe, and *vice verſâ.* As this remarkable property may be traced, in its conſequences, through almoſt all electrical appearances, I cannot but think it merits great attention, and, when it comes to be better underſtood, may throw much light upon the ſyſtem of electricity. However that may be, it was impoſſible for me not to obſerve, that it runs through the whole of that branch, which I have at preſent under examination, and to which I return.

White ſilk differs much in electricity from black ſilk. When the white ſtocking is drawn ſeparately upon the hand, no crackling is heard, nor ſparks of fire ſeen in the dark, let it be pulled backward and forward ever ſo often: when another white ſtocking is drawn on above it, nothing more appears: and, when ſeparated from the hand, neither of them diſcovers any ſigns of electricity, excepting that, when brought within a few inches of the electrometer, they attract and repel the balls a little.

If inſtead of two white or two black ſtockings, one white, and over that, a black ſtocking be drawn upon the hand, they diſcover not the leaſt ſigns of elec-

tricity

tricity while they continue upon the hand, even tho' they ſhould be drawn backwards and forwards upon it ſeveral times; nor, when taken together from the hand, and preſented to the electrometer, do they appear to have acquired any more than a very ſmall degree of electricity. They muſt be brought within the diſtance of a foot, nay, ſometimes of a few inches, before they have any effect upon the balls: but the moment they are ſeparated, they are found to be both of them highly electrified, the white *poſitively*, and the black *negatively*. The circumſtances, that appear the moſt to merit obſervation, are as follow:

1°.—When the electrometer is placed on a non-electric, and the black ſtocking is preſented to it at the diſtance of 3, 4, or 5 feet, according as it happens to be more or leſs powerfully electrified, the balls begin to be viſibly attracted, and when it is brought nearer, they are ſeen to be agitated in a violent manner. If, inſtead of the black, the white ſtocking be preſented at the ſame diſtances, it is found to have preciſely the ſame effects, attracting and agitating the balls in the very ſame manner: From whence it appears, that whatever difference there was between the electricity of the black and the white, under other circumſtances, they each of them acquire an equal degree of electricity, by being electrified together.

2°.—When the electrometer is ſupported by glaſs, and the white ſtocking is preſented to it, it firſt attracts the balls, and afterwards repels them; when taken away, it leaves them in a repulſive ſtate with regard to each other; when brought back, it repels them as before. If, in place of the white, the black be now preſented, the balls are immediately attracted, ſoon after again repelled, and left once more in a repulſive ſtate with regard to each other. If the white be again preſented, the ſame train of effects takes place as before; and ſo on, alternately, as in the caſe of the clear and opaque glaſs tubes, when excited; the white ſtocking anſwering preciſely to the clear, and the black to the opaque tube, and acting the one *poſitively*, the other *negatively*, at full as great a diſtance, and as forcibly, as the tubes.

3°.—Both the ſtockings, when held at a diſtance from one another, appear inflated to ſuch a degree, that, when highly electrified, they give the intire ſhape of the leg; and when brought near the face, or any naked part of the body, there is a ſenſation felt, as if a cool wind was blowing upon that part. When the two white, or the two black, are held together by the extremities, they repel one another, and form an angle, ſeemingly of 30 or 35 degrees.

4°.—When a white and a black ſtocking are preſented to each other, they mutually attract, with a force anſwerable to the degree of electricity they have acquired: when brought within the diſtance of three feet, they uſually incline towards one another: within two and a half, or two feet, they catch hold of each other; and when brought nearer, they ruſh together with ſurpriſing violence. As they approach, their inflation gradually ſubſides; and their attraction of foreign objects diminiſhes: when they meet, they flatten, and join as cloſe together, as if they were ſo many folds of ſilk; and then the balls of the electrometer are not affected at the diſtance of a foot, nor even of a few inches at certain times. But what appears moſt extraordinary, is, that when they are ſeparated, and removed at a ſufficient diſtance from each other, their electricity does not appear to have been in the leaſt impaired by the ſhock they had in meeting. They are again inflated, again attract, and repel, and are as ready to ruſh together as before *. When this experiment is performed with two black ſtockings in one hand, and two white in the other, it exhibits a very curious ſpectacle: The repulſion of thoſe of the ſame colour, and the attraction of thoſe of different colours, throws them into an agitation that is not unentertaining, and makes them catch each at that of its oppoſite colour, at a greater diſtance than one would expect. When allowed to come together, they all unite in one maſs; when ſeparated, they reſume their former appearance, and admit of the repetition of the experiment as often as you pleaſe; till their electricity, gradually waſting, ſtands in need of being recruited.

5°.—When they are ſeparated from one another, they loſe their power very ſoon, much as the excited tube does; but when they are together, they will retain it for an hour or two, and longer, when the air

---

* The phenomena, here remarked, of the black ſtocking and the white when electrified; namely, that, as they approach one another, their attractive and repulſive force decreaſes, with regard to foreign objects, but increaſes ſurpriſingly, with regard to each other; and that their electricity ſuffers no diminution from the ſhock of their congreſs, appear to me to be obſervations new in electricity, and to merit attention. They ſeem to point out a retentive power of electricity, which takes place between electrics and electrics only; and which, I apprehend, may be found to be the cauſe of many curious and ſingular phenomena.

is in a ſtate favourable for electricity. While they are aſunder, and any non-electric is brought near them; if that non-electric is of a broad ſurface, it is with difficulty they are diſcharged of their electricity; but if the point of any, eſpecially of a metallic, body, be preſented, they are inſtantaneouſly deprived of their electrical virtue: but if they be in conjunction together, they retain their electricity with ſo much obſtinacy, that even the ſharpeſt point of metal cannot deprive them of it. In this, and in ſome other reſpects, there appears to be ſuch a reſemblance between the Leyden phial, or the electrical pane of glaſs, and the black ſtocking in conjunction with the white, eſpecially when the one is within the other, that I have been induced to conſider them both in the ſame light. In both caſes, the *poſitive* electricity is on the one ſide, and the *negative* on the other; and the ſtockings, as well as the phial, and the pane of glaſs, are at once electrified *poſitively* and *negatively*. In both caſes there is an accumulation of electricity, and a retention of it, far beyond what is to be met with in a ſimple body, electric or non-electric. There is, however, a very remarkable difference between them in two reſpects. In the phial, and in the pane of glaſs, an exploſion is always obtained by carrying on a communication between the two ſides by the interpoſition of a non-electric; but, in the caſe of the black ſtocking and the white, I never yet have been able to procure an exploſion, nor ſo much as a ſpeedy diſcharge, by any means I could think of, while the one was within the other. I have put one hand within the innermoſt, and with my other have claſped the outward ſtocking; nay, I have thruſt in my hand, and turned the ſtockings inſide out, and, in that condition, have daſhed them againſt the floor; and all this without procuring the leaſt perceptible diſcharge. On the other hand, the phial and the pane of glaſs afford no opportunity of ſeparating the *poſitive* from the *negative* electricity, ſo as to ſhew them intire and diſtinct from each other; whereas we need only pull the ſtockings aſunder, and then in the white we find the *poſitive*, and in the black the *negative* electricity.

6°.—When the ſtockings are ſeparated, and in the dark, upon preſenting to them the point of one's finger, or any ſmall metallic body, rounded at the end. they exhibit the appearance of electrical fire or light, according to the *negative* or *poſitive* ſtate of the ſtocking the object is preſented to. With the black, at the diſtance of two or three inches, there appears to dart from the end of one's finger a ſprig or pencil, as it were, of fiery ſparks, which dilates in its progreſs, and ſtrikes againſt the ſurface of the ſtocking: at the ſame time a crackling, or ſnapping noiſe, is heard. When the firſt diſcharge is made, upon preſenting the finger to a freſh part of the ſtocking, the ſame phenomenon is repeated, till you have traverſed the whole length of the ſtocking, which, when the finger moves ſlowly, uſually yields eight or ten diſtinct diſcharges, before it is diveſted of its electricity. With regard to the white ſtocking, the ſame appearances hold; but with this difference, that, inſtead of ſparks of fire iſſuing from the finger, a little globule of white or blueiſh light is ſeen at the point of it; and, when the electricity is ſtrong, that little body of light ſeems to break in an exploſion between the ſtocking and the finger; and rather a hiſſing than a crackling noiſe is heard.

7°.—The electrical phial may be charged by the ſtockings, either *poſitively* or *negatively*, according as the wire from the neck of the phial is preſented to the white or the black; and in the one, or the other caſe, the hiſſing, or the crackling noiſe, is louder than when any common wire, or non-electric body, is preſented: but if the electricity of the white ſtocking be thrown into the phial, and upon that the electricity of the black, or *vice verſâ*; in that caſe, the phial will not be electrified at all.

The charging of the phial was among the firſt of my experiments with electrified ſtockings. By ſome trials I made in the month of December laſt, I found it would ſucceed. One froſty evening in that month, having thrown into a ſmall phial, filled with quickſilver, the electricity of one black ſtocking, I received from the exploſion a ſmart blow upon my finger. With the electricity of two ſtockings, the blow reached both my elbows; and, by the means of four, I kindled ſpirits of wine in a tea-ſpoon, which I held in my hand, and, at the ſame time, I felt the blow from my elbows to my breaſt. It may not, however, be improper to obſerve, that the electricity, in this caſe, was excited by means of the leg.

From what hath been ſaid in the preceding pages, it is evident, that all the remarkable appearances of electricity, hitherto diſcovered, may be exhibited by a ſimple apparatus of black and white ſilk. But this is not all: in the courſe of experiments above-mentioned, ſomething curious has occurred to my obſervation, of which I do not find that any notice has been taken by others.—What I mean is, a ſtrong cohesion produced by electricity. But as this paper is already extended to a great length, I ſhall reſerve the account of electrical coheſion for another, which I ſhall ſoon have the honour of preſenting to the Society.

PAPER III.

Of Electrical Coheſion.

PATENT OFFICE LIBRARY

Read June 21, 1759. ACcording to what I promiſed in the concluſion of my laſt paper, I come in this to give the Society an account of coheſion produced by electricity. I had not made any great progreſs, in the ſeries of experiments and obſervations I have already had the honour to communicate, before I perceived that the black and white ſtocking, when electrified, and allowed to come together, not only joined extremely cloſe, but actually ſtuck to each other; inſomuch that unleſs when weak in electricity, or improperly applied, I could make the white bear the weight of the black, or the black that of the white, and that for a conſiderable time. But as the weather, for ſome months in winter, was ſo ſeldom favourable for electrical experiments, that I had ſcarcely opportunities ſufficient to ſatisfy myſelf with regard to other points, I did not enter upon an examination of this phenomenon experimentally, till about the latter end of March. By that time, I had got ready the ſcale of a balance properly fitted with a hook to catch hold of the ſtocking, a ſet of Troy-weights I could depend upon, and an exact pair of ſcales, to take the preciſe weight of the ſtockings as occaſion ſhould require.

By experience I found that the ſame pair of ſtockings did not always do equally well, even independently of the weather; and that, by being too frequently electrified at a time, their virtue appeared to diminiſh. I therefore judged it proper to be provided with changes of pairs; and that there might be the greater conformity between the experiments, I choſe them as exactly as poſſible of the ſame ſize and ſubſtance. The ſort I fixed upon, is what is called half gauze; the weight of the white ſtocking, at an average, 18 *dwt.* and 10 *gr.* but when died black, 1 *oz.* and 1 *dwt.* the weight being increaſed, by the dying of that colour, above 5 *dwt.* in the pair. When the white and the black ſtocking were warmed at the fire, ſo as to be prepared for electricity, they uſually loſt about a twentieth part of their weight; ſo that in the courſe of my experiments I rate the white at 17 *pwt.* and ¼, and the black at 1 *oz.* The ſcale, with the ſilk lines that belonged to it, and the hook, was adjuſted preciſely to the weight of 1 *oz*; and as I commonly meaſured the ſtrength of coheſion by fixing the hook to the black ſtocking, and taking hold of the white, I had but to make an allowance of 2 *oz.* more than the weights put into the ſcale, ſo as to take the preciſe weight the ſtockings could raiſe by the power of coheſion.

I meaſured this power two different ways; the firſt whilſt the one ſtocking was ſtill within the other; ſecondly,

condly, when ſeparated, and the one afterwards applied externally to the other. In the firſt of theſe caſes, it may be thought that an allowance ſhould be made for the friction in pulling the ſtockings aſunder; but that appeared to me to be very inconſiderable; for when thoſe of the ſame colour were put one within the other, and inverted, they dropped aſunder of themſelves; or if there was any intanglement about the heel, a little ſhaking diſengaged and ſeparated them: however, if it ſhould be thought proper, the allowance of an ounce may be made, by deducting ſo much from the weight reſpectively found.

I have but one circumſtance more to mention, before I proceed to give the reſult of my experiments; which is, that we muſt not be ſurpriſed, when we find the force of coheſion externally, to be in no regular proportion with that within; for when the ſtockings are highly electrified, they ruſh together with ſuch impetuoſity, that it is extremely difficult to direct their motion, and make them meet in the manner moſt advantageous for coheſion.

In the experiments I have made, to meaſure the force of electrical coheſion, I have always found it anſwerable, ſo far as I could judge from appearances, to the degree of electricity at the time excited. When the ſtockings have been but weakly electrified, I have found them unable to ſupport the weight, the one of the other. When in a more powerful ſtate of electricity, I have known them to raiſe, reſpectively, from one to twelve ounces, and upwards; nay, once I found the coheſion ſo ſtrong as to move ſeventeen ounces, including the ſcale and the black ſtocking. For the ſake of accuracy, I ſhall give a particular account of the reſult of a few of my moſt remarkable experiments, as I find them in the notes, which I took at the time of making them.

The firſt I find is of the 30th of March; the wind at north-eaſt; the weather clear, inclining to froſt. The white ſtocking within the black, raiſed the weight of 1 *lb.* 1 *oz.* 6 *dwt.* ½, half a pennyweight more ſeparated them. I find no note here taken of the weight born by the ſtockings applied externally to each other.

April 6. A hazy and wet morning; but the wind at north-eaſt. With new ſtockings; the white, being within the black, raiſed 11 *oz.*—without, 6 *oz.* With another pair, that had been much uſed in experiments; the white, within, raiſed 6 *oz.*—without, 3 *oz.*

April 16. A clear dry morning; the wind at north-eaſt; Fahremheit's thermometer at 48. Of the new, the white ſtocking, within, raiſed 1 *lb.* 5 *oz.*—without, 6 *oz.* 15 *dwt.*—Of the old, the white ſtocking, within, raiſed 8 *oz.*—without, 5 *oz.* 15 *dwt.*——

The laſt obſervation I find marked, is of the 19th of May; the weather clear; the wind at north-eaſt; the thermometer at 55. The white, within the black, raiſed 10 *oz.*—and without, 6 *oz.*

It is to be remarked, that by this time I had got the old ſtockings waſhed; and now there appeared little or no difference between the power of them and of the newer pairs; though the latter had ſtill the advantage.

In making the experiments, it was neceſſary to loſe as little time as poſſible, on account of the waſte of electricity: I could therefore ſeldom proceed to the accuracy of fractions of a penny weight; nor often indeed of thoſe of an ounce; and this is the reaſon that my notes run generally in round numbers, which, however, may be depended upon.

The greateſt weight I have been able to raiſe by the force of electrical coheſion, as appears above, has been ſeventeen ounces. Now the white ſtocking, which weighed but 17 *dwt.* and an half, bore all this weight: in this caſe therefore it raiſed, by the ſtrength of its coheſion with the black, 340 pennyweight; that is, nearly twenty times its own weight *. And if we conſider that the force, applied to ſeparate them, acted in a direction parallel to the ſurfaces, by which they cohered; and that when the ſurfaces are ſmooth, a force acting in ſuch direction, has much greater influence in ſeparating bodies, by making them ſlide gently over one another, than if thoſe bodies were rigid, and the force employed to ſeparate them acted in a direction perpendicular to the cohering ſurfaces; when we conſider this, I ſay, it will be hard to determine how great the ſtrength of their coheſion may be.

---

* As the experiments mentioned above were made in the ſpace of ſix or ſeven weeks from about the latter end of March, when the temperature of the air begins to be leſs favourable for electricity, I did not doubt, but upon the approach, and during the progreſs of the enſuing winter, I ſhould meet with inſtances of a ſtronger degree of coheſion, than I had before been able to aſcertain. Accordingly, ſince this paper was read in the Royal Society, and particularly in the months of November, December, and January laſt, at times, when the weather was clear and froſty, I found that the ſame ſtockings lifted conſiderably more, than I had been able to make them do in the preceding months of March, April, and May. I likewiſe found, that when the ſtockings were perfectly new, or the black dipt afreſh, and the white newly cleaned and ſulphured, as alſo, that when they were of a more ſubſtantial make, ſuch as thoſe that are wove of ſpun ſilk, weighing commonly about the double of thoſe that go by the name of half gauze, their power of coheſion, when favoured by the temperature of the air, increaſes to a very conſiderable degree. Under thoſe circumſtances, at particular times, I have been able to make the black ſtocking, or the white, when the rough ſides of each were put together, raiſe (the half gauze) from 20 to 40, and (of ſpun ſilk) from 40 to 90 times its own weight. Vide the ſubſequent letter from Dr. John Mitchell to the Rev. Dr. Birch.

The experiment may be tried with two plates of glaſs, the one electrified *poſitively*, the other *negatively*. As in that caſe the principle, upon which the coheſion of the white with the black ſilk depends, would take place, I make no manner of doubt but the effect would be the ſame. I have not had an opportunity of trying the experiment: but I ſhould expect that the two plates would be found to cohere with greater force, than I have been able to aſcertain in the ſtockings; as a contrivance might be made to pull them aſunder in a direction perpendicular to their cohering ſurfaces.

The force with which the black and the white ſtocking cohere, is not the only thing remarkable in their junction. The ſolution of that coheſion, and the different degrees of tenacity, according to different circumſtances, afford ſome curious obſervations.

When the black and the white ſtocking are in coheſion with each other, if another pair, more highly electrified, be ſeparated, and preſented to the former ſtill in conjunction, the black to the white, and the white to the black; in that caſe, the coheſion of the firſt pair will be diſſolved, and each ſtocking of the ſecond, will carry off that of its oppoſite colour adhering to it. If the degree of electricity of both pairs be equal, the coheſion of the firſt pair will be weakened, but not diſſolved; and all the four will cohere, forming as it were one maſs. If the ſecond pair be but weakly electrified, the coheſion of the firſt pair with one another will be but little impaired, and that of the ſtockings of the ſecond with thoſe of the firſt, will be weak in proportion And laſtly, if the ſecond pair be not at all electrified, or if, in their place, any other body not electrified be preſented, there will be no effect produced on either hand.

White ſilk and black, when electrified, not only cohere with each other in the manner ſhewn above, but when in a high degree of electricity, are found, both one and the other, to adhere to bodies of broad and even, or poliſhed ſurfaces, though thoſe bodies be not electrified. This adheſion I diſcovered accidentally. While I was about ſome electrical experiments, having, without deſign, thrown a ſtocking, that was highly electrified, haſtily out of my hand, I was ſurpriſed to find it ſome time after, ſticking againſt the paper-hangings of my room. This led me to make the following experiments.

I preſented the white and the black ſilk, highly electrified, and in coheſion with each other, to the hangings; but no effect was produced. I then ſeparated the black from the white, and preſented them ſingly; in that caſe each of them readily adhered to the hangings, which they likewiſe did when flung from a little diſtance, and continued there for near an hour before they dropped. Having ſtuck up the black and the white, in the manner above-mentioned, I came with another pair of ſtockings highly electrified, and applying the white to the black, and the black to the white, I carried them off from the wall hanging on thoſe that had been applied to them. When the ſecond pair were electrified, but to a moderate degree, on applying them, in the manner above deſcribed, the former immediately quitted their hold of the hangings, and dropped to the ground. The ſame experiments held with the painted boards of the room; and likewiſe with the looking-glaſs; to the laſt of which, both the black and the white ſilk, appeared to adhere more tenaciouſly, than to either of the former.

I am afraid I have preſumed too much on the patience of the Society, by giving ſo full a detail of my experiments and obſervations, on a branch of electricity, that takes its riſe from ſo ſingular, and ſo mean a ſubject as that of black and white ſilk: But however particular the ſubject may be, the properties of electricity that are thence experimentally deduced are of a general nature, and muſt find a place in every true ſyſtem of electricity. If any apology be wanted, the beſt I can make, is to endeavour to draw ſuch inferences from the experiments above recited, as may poſſibly throw new light upon the theory of electricity.

But leſt I ſhould ſwell this paper to too large a ſize; and as the ſeaſon is at hand when the Society uſually adjourns for ſome months; I think it beſt to defer any matter I may have to offer, concerning the theory of electricity, till a convenient time after our next meeting. I ſhall only beg leave at preſent, to mention one or two things, which I have not hitherto had a proper opportunity of throwing out.

It hath been ſaid, that the influence of colours in electricity is no new diſcovery; that Monſ. Du Fay had treated at large upon the ſubject; and, after a variety of experiments, had concluded, that colours, as ſuch, had no effect in electricity; but that whatever was remarkable in that way, was owing to the change, which the ingredients of the dye produced upon the coloured body. I had not then ſeen what Monſ. Du Fay wrote upon the ſubject; but as I have ſince, I ſhall take the liberty to ſtate this matter fairly.

The late Monſ. Du Fay, an ingenious member of the Academy of Sciences at Paris, to whom we owe ſome valuable diſcoveries in electricity, gives an account of what is here alluded to, in a memoir, preſented in the year 1733. Electricity was at that time in its infancy; Mr. Hawkſbee had, but a little before, publiſhed an account of his experiments; which brought ſuch ſurpriſing appearances of electricity to light, as could not but induce the curious to turn their eyes upon that ſubject. In the courſe of thoſe experiments, he had taken notice of ſomething remarkable with regard to colours. Mr. Gray ſucceeded, and having opened a new path, made ſtill further diſcoveries in electricity: he likewiſe, in giving an account of what he had obſerved, hinted at ſomething curious with regard to colours. But neither of them appear to have come to any determined point in this matter. Monſ. Du Fay, who concurred with Mr. Gray, in carrying on electrical diſcoveries, with a candour and ingenuity that did honour to them both, having entered upon an enquiry (the ſubject of the memoir above-mentioned) to determine what ſort of bodies were moſt ſuſceptible of electricity, thought proper, in conſequence of what had fallen from Mr. Hawkſbee and Mr. Gray, to examine what effect the different colours had in augmenting or diminiſhing the electricity of different ſubſtances.

Accordingly he ranged a number of ribbands, of all the primitive colours, hanging them in the ſame vertical plane; and to theſe he applied an excited glaſs tube, in an horizontal direction.—Upon this he obſerved, that the black was firſt attracted; and, as he brought the tube nearer, the white next; and the reſt ſucceſſively, though not always in the ſame order. He made another experiment, in the ſame view, with gauzes of different colours, through which he tried the force of an excited tube, upon light bodies placed at a proper diſtance behind them: and from the reſult he was of opinion, there was ſomething in the influence of colours. But having afterwards tried ſome experiments with the coloured rays of the ſun as refracted by a priſm, with flowers of different colours, and with white ribbands rubbed over with differently coloured ſubſtances, he began to change his opinion. He likewiſe had recourſe to what he calls a deciſive experiment: he dipped his different-coloured ribbands in water; and when they were all equally wetted, he applied his tube, and found they were all equally attracted. From this laſt-mentioned experiment, in particular, he concluded that colours, as colours, had no effect in electricity; but that all was owing to the ingredients of the dye imbibed by the coloured body.

It is not my purpoſe here to inquire, whether Monſ. Du Fay's concluſion is well or ill founded. Whatever may be the deciſion of that point, I apprehend the whole of this affair hath very little concern with what hath been the ſubject of theſe papers, and could have been of little uſe to me, had I been acquainted with it before.

The ſeries of my experiments, however inconſiderable they may prove in the reſult, have taken a turn I did not at firſt foreſee. I ſet out with inquiring into the nature of an electricity, that ſeemed to have ſome connexion with the human body: I had made but little progreſs when I was ſurpriſed with an appearance of electricity, ariſing from the contraſt of two colours, or coloured bodies of the ſame ſubſtance: I met with it in my experiments, perpetually *poſitive* and *negative*; and under that appearance have followed it through a variety of its operations. The notions it hath led me to conceive, are different from thoſe I had before entertained of electricity. Such as they are, they ſhall, in due time, be freely ſubmitted to the judgment of the Society.

Having been told by one or two of my friends, that they had tried ſome of the experiments mentioned in the preceding papers, but could not get them to ſucceed; I beg leave to add a few words, before I conclude, by way of caution to any, who may have a curioſity to verify my experiments.

However eaſy it may ſeem to be, to follow the directions I have already given in electrifying the ſtocking, I am ſenſible from my own experience, that an attention to a number of little circumſtances, beſides ſome ſmall degree of addreſs, is requiſite, in order to make it ſucceed readily. This is known to have been the caſe with the electrical tube and globe: few people, at firſt, knew how to manage them ſucceſsfully; and yet glaſs is not ſo much expoſed to many inconveniencies, that affect electricity, as ſilk. To give but one inſtance of this: we know that a very ſmall quantity of duſt, greaſe, or any other matter that ſticks to the tube, will injure its electricity: Now this is what may eaſily be wiped off from glaſs; but it may be very difficult to clear the ſilk of it, as ſilk is of a nature more apt to imbibe, and to retain extraneous matter than glaſs.——From theſe conſiderations, I ſhould not be ſurpriſed at any perſons being diſappointed, as to the ſucceſs of their experiments, in a few trials; but I ſhould think it not fair for them to conclude from thence, that thoſe above-recited are not to be depended upon*. Yet, if any member of the Society, who is curious in theſe matters, hath not been able to ſatisfy himſelf with regard to any particular experiment, I ſhall think it no trouble to ſhew him, at any proper time, how it ſucceeds with me.

---

* The circumſtances neceſſary to be attended to, in order to procure the moſt conſiderable appearance of electricity, are as follow. 1°. That the wind be in the north, north eaſt, or eaſt; the weather clear and froſty, or inclining to froſt. 2°. That the ſtockings be of ſilk; one of a good black, the other of a clear white; and both of the ſame ſize and ſubſtance. 3°. That they be new; or be kept carefully wrapt up in paper, and only uſed in electrical experiments. 4°. And laſtly, That they be dried before the fire, and warmed to about the degree of heat of the human body, before they be drawn upon the hand or leg. And when taken off, care ſhould be had in ſeparating them, ſo as to keep them at a diſtance from one's clothes, or any thing that may leſſen their virtue. The circumſtances above-mentioned, might be gathered from what has been ſaid in theſe papers; but I thought it not amiſs to bring them together in this note.

PAPER IV. PART I.

Of Two diſtinct Powers in Electricity.

Read Dec. 20, 1759. I Obſerved, in the papers I have already had the honour of communicating to the Society, that the different ſtate of electricity, as diſtinguiſhed into *poſitive* and *negative*, was a leading circumſtance in all electrical appearances; and that, if followed out with due attention, it might bring us to a clearer view, than we yet have had, of the powers that nature employs in thoſe wonderful operations. Nothing could be more proper to ſerve this purpoſe, than the ſimple apparatus I had all along made uſe of. It conſiſted of two electric bodies, of which, when they were excited, one never failed to aſſume the poſitive, the other the negative ſtate of electricity. The obſervations I had frequent opportunities of making, with regard to the manner in which they acted, in theſe different ſtates, on other bodies, and on each other reciprocally, confirmed me in a notion, which, in the courſe of my experiments, I had very early conceived.

My notion is, that the operations of electricity do not depend upon one ſingle poſitive power, according to the opinion generally received; but upon two diſtinct, poſitive, and active powers, which, by contraſting, and, as it were, counteracting each other, produce the various phenomena of electricity; and that, when a body is ſaid to be poſitively electrified, it is not ſimply that it is poſſeſſed of a larger ſhare of electric matter than in a natural ſtate; nor, when it is ſaid to be negatively electrified, of a leſs; but that, in the former caſe, it is poſſeſſed of a larger portion of one of thoſe active powers, and in the latter, of a larger portion of the other; while a body, in its natural ſtate, remains unelectrified, from an equal ballance of thoſe two powers within it.

I do not here undertake to give a ſyſtem of electricity. It is the deſign of this paper to propoſe the grounds of my opinion, only ſo far as it reſts upon obſervation and experiment. If the proofs I have to offer ſhall be found concluſive, and it be allowed, that two diſtinct and counteracting powers prevail in electricity, one of them correſponding with the poſitive, and the other with the negative ſtate; in that caſe, the truth thus eſtabliſhed, may afterwards be aſſumed as a principle in theory; and we may try how far it will ſerve in accounting for the various appearances of electricity. But even then, I ſhould not think of troubling the Society with diſcuſſions of ſo great a length, and of ſo ſpeculative a nature, as thoſe uſually are that relate to theory.

I might bring arguments to prove the exiſtence of two diſtinct powers in electricity, from a variety of obſervations and experiments, ſome of them taken from among thoſe mentioned in the preceding papers: But as the bounds I preſcribe to myſelf in this, do not permit me to enter upon ſo large a field, I ſhall confine myſelf to ſuch obſervations only, as have fallen within my notice, in one particular branch of electricity, that which relates to the Leyden phial.

All who allow of *poſitive* and *negative* electricity, know, that the phial, when charged, exhibits electricity in thoſe two ſtates, the one within, the other on the outſide; and that when a communication is made between the two, by the means of a non-electric touching the coating, and at the ſame time approaching the wire, or *vice verſâ*, the exploſion is produced, and the phial diſcharged. This reduces the queſtion to a narrow compaſs; for if, upon the diſcharge of the phial, we meet with proofs not only of a power acting from within to the outſide, but alſo of a power acting at the ſame inſtant from the outſide to within, then, I think, we may fairly conclude, that what is called *negative* electricity is, in reality, a poſitive active power; and that electricity, in general, conſiſts not of one alone, but of two diſtinct, poſitive powers, acting in contrary directions, and towards each other.

The proof I ſhall offer firſt, is founded on the following experiment. When the phial is electrified but a little, if we touch the coating of it with a finger of one hand, and at the ſame time approach a finger of the other hand to the wire, we ſhall receive a pretty ſmart blow upon the tip of each of the fingers, the ſenſation of which reaches no farther: If the phial be electrified a degree higher, we ſhall feel a ſtronger blow, reaching to the wriſts, but no farther: When again it is electrified to a ſtill higher degree, a ſeverer blow will be received; but will not be felt beyond the elbows: Laſtly, when the phial is ſtrongly charged, the ſtroke may be perceived in the wriſts and elbows;

but the principal ſhock is felt in the breaſt, as if a blow from each ſide met there. This plain and ſimple experiment ſeems obviouſly to ſuggeſt to obſervation, the exiſtence of two diſtinct powers, acting in contrary directions: And I believe it would be held as a ſufficient proof by any who ſhould try the experiment, with a view to determine the queſtion ſimply from their own perceptions.

But as I am ſenſible, that the proof of any important point in philoſophy, ought not to depend upon the perceptions of this or that particular perſon, I judged it neceſſary to have recourſe to experiments, the reſult of which might admit of no ambiguity. The fortunate diſcovery of M. Muſchenbroek and M. Allamand, with the improvements that have ſince been made upon it, puts it in our power to increaſe electricity to what degree we pleaſe. I did not therefore deſpair of the means of bringing this matter to a fair deciſion. I expected, that if an electrical ſtroke ſhould be made to paſs through a ſolid body, with ſo much force as to pierce and tear the ſubſtance of it, ſuch marks would be left, as might enable us, with certainty, to trace the courſe of the electrical power in its paſſage through the body.

Having no apparatus of my own capable of producing ſuch effects, I had recourſe to a worthy member of this Society, doctor Franklin, who was poſſeſſed of a very good one. I had communicated all my obſervations to this gentleman as they occurred, and, in return, met with an ingenuity and candour, that render him as eſtimable in private life, as the improvements he has introduced into electricity, and particularly his diſcovery in relation to thunder and lightning, will render his reputation laſting in the learned world. We differed in opinion with regard to the point in queſtion; nevertheleſs I found him ready to give me all the aſſiſtance in his power, for bringing the matter to a fair deciſion. I had ſeen him pierce a quire of paper with a ſtroke of electricity; and as I perceived it had been ſtruck ſeveral times before, I deſired he would give it me, that I might at leiſure examine the effects of the ſundry ſtrokes.

When I came to do ſo, I obſerved, that at every hole which had been made through the quire, the upper and the under leaf (for the quire had been laid in an horizontal poſition when it was ſtruck) were ragged about the orifice, and thoſe ragged edges pointed moſtly outwards from the body of the quire. But what was more material; when I came to turn over the leaves, I found, that the edges of the holes were bent regularly two different ways (and more remarkably ſo about the middle of the quire), one part of each hole upwards, and the other part downwards; ſo that, tracing any particular hole as it traverſed the quire, I found on one ſide the fibres pointed one way, and on the other ſide the other way; much in ſuch a manner, as if the hole had been made in the quire, by drawing two threads in contrary directions through it.

This was not all: A piece of paper, covered on one ſide with Dutch gilding, had been accidentally left between two leaves in the quire, and had been pierced by two different ſtrokes. This exhibited a very remarkable appearance: Where each of the ſtrokes had been given, the gold leaf was ſtripped off, and had left the paper bare for a little ſpace, in an oblong form, rounded at the ends; in which, at the diſtance of about a quarter of an inch from each other, appeared two points, one of them a little round hole, the other only an indent or impreſſion, ſuch as might have been made by the point of a bodkin. In the leaf, which fronted the gilding, two ſuch points likewiſe appeared, correſponding to thoſe above-mentioned; ſo that the hole in the one was oppoſite to the impreſſion in the other, but ſurrounded with little black or blueiſh circles. When the hole, which had been ſtruck in the quire, was traced from above down to the gilding (for the gilt paper happened to lie with its gilded ſide uppermoſt), it was found to terminate on the point in the gilt paper where the impreſſion appeared, and there the impreſſion pointed downwards. Again, when the hole in the lower part of the quire was traced from below upwards, it was found to terminate on the point in the leaf fronting the gilding, where the impreſſion was, and there the impreſſion pointed upwards. The facts above-mentioned ſeem to leave it without doubt, that the ſtroke had been given, at the ſame inſtant, upwards and downwards; but that the electrical power from above, and from below, had ſeized upon the gilding, diſſipated part of it in vapour, and by that means become ſo weak, that each of them could afterwards only make an impreſſion upon the paper, marking the reſpective directions of their courſe.

I communicated theſe obſervations to Dr. Franklin; but as no concluſion can, with certainty, be drawn but from facts, confirmed by repeated trials, I deſired to have the ſatisfaction of making a few experiments with him in relation to this matter; to which he readily conſented. For that purpoſe I waited upon him one morning about the middle of June laſt; and the better to aſcertain what was eſſential in the facts, I varied the circumſtances a little from thoſe above.

In the middle of a paper-book of the thickneſs of a quire, I put a ſlip of tin-foil; and in another of the ſame thickneſs I put two ſlips of the ſame ſort of foil, including the two middle leaves of the book between them. Upon ſtriking the two different books, the effects were anſwerable to what I expected. In the firſt, the leaves on each ſide of the foil were pierced, while the foil itſelf remained unpierced; but, at the ſame time, I could perceive an impreſſion had been made on each of its ſurfaces, at a little diſtance one from another; and ſuch impreſſions were ſtill more viſible upon the paper, and might be traced as pointing different ways. In the ſecond, all the leaves of the book were pierced, excepting the two that were between the ſlips of foil; and in theſe two, inſtead of holes, the two impreſſions, in contrary directions, were very viſible.

I have lately got an electrical apparatus of my own, formed on the model of that of Dr. Franklin's, and have had opportunity ſince, of making frequent repetitions of the experiments above-mentioned. Notwithſtanding ſome little variation in appearances, ariſing, as in other electrical experiments, from the particular ſtate of the weather, the different degree of electricity, or other accidental circumſtances, I have met with nothing but what confirms me in my opinion of two diſtinct counteracting powers. All the remarks I have been able to make in the repetition of experiments, that need to be added to what I had before obſerved, may be reduced to the three following.

1°. When a quire of paper, without any thing between the leaves, is pierced with a ſtroke of electricity, the two different powers keep in the ſame tract, and make but one hole in their paſſage through the paper: not but that the power from above, or that from below, ſometimes darts into the paper at two or more ſundry points, making ſo many holes, which, however, generally unite before they go through the paper. What I mean is, that I never yet could obſerve the two powers to make different holes in the paper; but that they always keep the ſame common channel, ruſhing along it with inconceivable impetuoſity, and in contrary directions. They ſeem to paſs each other much about the middle of the quire; for there the edges are moſt viſibly bent different ways: whereas in the leaves near the outſide of the quire, the holes very often carry more the appearance of the paſſage of a power iſſuing out, and exploding into the air, than of one darting into the paper.

2°. When any thin metallic ſubſtance, ſuch as gilt-leaf, or tin-foil, is put between the leaves of the quire, and the whole ſtruck; in that caſe, the counteracting powers deviate from the directeſt tract, and leaving the path they would in common have taken through the paper only, make their way in different lines to the metallic body, and ſtrike it in two different points, diſtant from one another about a quarter of an inch, more or leſs (the diſtance appearing to be leaſt when the power is greateſt;) and whether they pierce, or only make impreſſions upon it, in either caſe, they leave evident marks of motion from two different parts, and in two contrary directions. It is this deviation from a common courſe, and the ſeparation of the lines of direction conſequent upon it, that affords us the ſtrongeſt proof, of the exertion of two diſtinct and counteracting powers.

3°. When two ſlips of tin-foil are put into the middle of the quire, including two or more leaves between them, if the electricity be moderately ſtrong, the counteracting powers only ſtrike againſt the ſlips, and leave their impreſſions there. When it is ſtronger, we generally find one of the ſlips pierced; but ſeldom both: and from what I have obſerved in ſuch caſes, it would ſeem as if the power, which iſſued from the outſide of the phial, acts more ſtrongly than that which proceeds from within; for the lower ſlip is moſt commonly pierced: But that may be owing to the greater ſpace, the power from within has to move through, before it ſtrikes the paper.

I take the liberty to lay before the Society a paper-book, of the thickneſs of a quire, ſtruck three times in the manner above deſcribed. The firſt ſtroke (A) is given, when there is nothing between the leaves of the book. The ſecond (B) when a piece of paper, covered on one ſide with what is commonly called Dutch gilding, is laid in the middle. The third (C), when two ſlips of tin-foil are put into the book, including the two middle leaves between them.

The members, who are curious in theſe matters, may, at their leiſure, examine the effects of the ſundry ſtrokes; and if any gentlemen, in particular, deſire the farther ſatisfaction of ſeeing the ſtrokes given, I ſhall be very ready, at any proper time, to comply with their deſire.

PAPER IV. PART II.

Of Two diſtinct Powers in Electricity.

Read Dec. 20, 1759. THE notion of two diſtinct electrical powers, acting in contrary directions, may appear to ſome to be the ſame with that of the *effluence* and *affluence* of electrical matter, which M. l'Abbé Nollet gives as the general cauſe of the phenomena of electricity *. It may therefore be not improper to take a nearer view of theſe two opinions, to ſee how far they agree, and in what they differ.

This ingenious author, whoſe merit in the learned world is very conſiderable, particularly with regard to his labours in electricity, had obſerved, that, when a body is electrified, a current of electric fluid iſſues from it, and, in the form of diverging rays, ſpreads through the air, and enters into other bodies; and that, at the ſame time, a current of electric fluid, iſſuing from other bodies, paſſes through the air, and, in the form of converging rays, enters into the body electrified. From thence he concludes, that a continued, and (to uſe his own terms) ſimultaneous * effluence and affluence of a fluid matter, extremely ſubtile, conſtitutes † electricity. Upon this principle he endeavours to account for all the phenomena that attend the electrification of bodies.

---

* "Plus de trois ans ſe ſont écoulés depuis que j'ai propoſé "comme la cauſe generale des phenoménes électriques, *l'effluence et l'affluence ſimultanées d'une matiere fluide, preſente par tout, et capable de s'enflammer par le choc de ſes propres rayons.*" Preface to *Recherches ſur l'electricité*, at the beginning.

What M. l'Abbé Nollet has obſerved with regard to two contrary currents in electricity, is by no means inconſiſtent with the principle of two diſtinct counteracting powers. On the contrary, the exiſtence of two ſuch currents is, according to my opinion, a neceſſary conſequence of the exertion of thoſe powers from one body upon another. It is a phenomenon of electricity only; not the principle upon which all electrical appearances depend.

But a more eſſential difference takes place between this gentleman's opinion and mine: he repreſents the two currents as conſiſting but of one and the ſame

---

* “ Ces deux courans qui ont des mouvemens oppoſes, ont lieu
“ tous deux enſemble, c'eſt ce que j'exprime par le mot ſimultanés.” *Lettres ſur l'electricité*, p. 30.

† “ L'electricité, comme je l'ai deja dit et prouvé ailleurs, n'eſt
“ pas ſeulment l'émanation d'une matiere qui s'elance du corps
“ électrisé ; c'eſt auſſi un remplacement continuel qui ſe fait de
“ cette matiere, par une autre tout-a-fait ſemblable, qui ſe porte
“ de toutes parts au corps électrisé ; c'eſt pour ainſi dire, un commerce de la matiere qui j'ai nommée effluente, et de celle que
“ j'ai appellée affluente. Si celle-ci vient à manquer, ou que la
“ premiere n'ait plus la liberté de ſortir, cet état ou *ce double*
“ *mouvement*, que l'on nomme *electricité*, doit bien-tot ceſſer.”
“ *Eſſai ſur l'electricité*, p. 202.

fluid ‡; admits but of one kind of electricity ‖; and maintains, that two bodies cannot be ſaid to be differently electrified, but as they are electrified in a higher or lower degree *. On the other hand, it is my opinion, that there are two electrical fluids (or emanations of two diſtinct electrical powers) eſſentially different from each other; that electricity does not conſiſt in the efflux and afflux of thoſe fluids, but in the accumulation of the one or the other in the body electrified; or, in other words, it conſiſts in the poſſeſſion of a larger portion of the one or of the other power, than is requiſite to maintain an even ballance within the body; and, laſtly, that according as the one or the other power prevails, the body is electrified in one or in another manner.

In thoſe reſpects we differ in opinion. Who is in the right is another queſtion. The whole ſeems to turn on a ſingle point, namely, whether there be but one, or if there are two diſtinct kinds of electricity. The bounds of this paper do not permit me to enter upon a full diſcuſſion of the point. I cannot, however, but obſerve, that the whole ſeries of experiments mentioned in the preceding papers, tends to confirm the diſtinction, formerly made, of electricity into two kinds; and to ſhew, that there is an eſſential difference (whatever it be that conſtitutes that difference) between what is commonly called poſitive electricity, and negative. A farther proof of that difference ariſes from the ſucceſs of an experiment, of which I threw out a hint in my third paper, and which I have ſince taken an opportunity of making, touching the electrical coheſion of glaſs. The experiment is as follows:

---

‡ *Eſſai ſur l'electricité*, p. 160, 161.

‖ Ibid. p. 118, 119.

* *Lettres ſur l'electricité*, p. 101. 105.

I took two panes of common window-glaſs, about nine inches ſquare, the thinneſt, the moſt even, and the ſmootheſt in their ſurfaces I could get. I covered one of the ſides of each with tin-foil, leaving the ſpace of near an inch from the edges uncovered. I warmed them a little at the fire; and, applying the two bare ſides together, I laid them upon four wine-glaſſes, which ſupported them at the corners. I then brought down a chain from the prime conductor, nearly to touch the coating of the upper plate, and applying a wire, which I held in my hand, to the coating of the under plate, the machine was put in motion, and the electrification performed, as in the caſe of the common electrical pane. When the operation was completed, I removed the chain and the wire, and taking hold of two oppoſite corners of the upper glaſs (thoſe correſponding to them in the other having been purpoſely cut away, I lifted it, and found, that the under glaſs came up with it. The coheſion appeared to me to be conſiderably ſtrong; but I had not any proper apparatus ready to meaſure the ſtrength of it. I laid them down again on the wine-glaſſes, and procured an exploſion, as in the caſe of the common electrical pane. I then took hold of the corners of the upper glaſs, and lifted it; but found, that the coheſion was diſſolved, the under glaſs remaining behind.

I could indeed perceive, that, after the diſcharge, there was ſtill ſome ſmall degree of coheſion between the plates, which felt as if ſome glutinous ſubſtance had got feeble hold of them: but this was no more than what I found took place between them, when, without being electrified, they were forced cloſe together. For that reaſon, two plates of glaſs, finely poliſhed, and ſo even as to come into cloſe contact through the whole extent of their oppoſed ſurfaces, would be very improper for this experiment; for, when the power of electricity had forced them into contact, the preſſure of the air, and a coheſion proceeding from another principle, would keep them together.

But to purſue the purpoſe of our experiment.—All who admit of the diſtinction of electricity into two kinds, agree, that as in the Leyden phial, ſo likewiſe in the electrical pane, the different ſides are differently electrified: That ſide, which more immediately receives its electricity from the glaſs globe, is ſaid to be poſitively, and the other negatively, electrified. What may be ſaid of the electrical pane, is applicable to the glaſs plates in this experiment; for, when they are put together in the manner mentioned above, they form an electrical pane between them; one of the plates correſponding with one of the ſides, and the other with the other ſide of the pane. When, therefore, the glaſs plates are electrified in the manner before deſcribed, the plate, which receives its electricity immediately from the chain, will, according to this diſtinction, be poſitively electrified, and that which receives its electricity from the wire, negatively.

Upon theſe conſiderations, we may expect, from the experiment in hand, the means of determining, whether the diſtinction of electricity into two different kinds is merely nominal, or if there is an eſſential difference between them: For after the glaſs plates have been electrified in one poſition, ſo as to be incapable of receiving any more electricity, if they be inverted, and in that new poſition preſented to the chain and wire, and the globe again be put in motion, according as one or other of thoſe opinions holds, correſpondent effects will follow. If the electricity, that comes by the chain, be of the ſame nature with that which comes by the wire, no change will be produced upon the plates; for being before full of one and the ſame kind of electricity, they can do no more than keep what they had, or exchange it for juſt as much of the ſame kind. But if, by the chain and the wire, two kinds of electricity, totally different in their nature, be conveyed into the reſpective plates, in that caſe it is to be expected, that the electricity that each of them had acquired in their former poſition, will be gradually deſtroyed, till no ſigns of electricity appear in either; after which, they will begin again to be electrified, having their electricity reverſed.

In order to ſee what would really happen, I repeated the experiment in the following manner: I electrified the two plates till they were fully charged, and in ſtrong coheſion, the ſnapping from the chain and the wire having totally ceaſed. I then turned them upon the glaſſes that ſupported them, applied the chain and the wire to the different ſides, and began to electrify as before. The glaſs globe was no ſooner in motion, than the ſnapping from the chain and the wire returned with violence; and the plates, which, in the former poſition, would receive no more electricity, appeared, in their new ſituation, to receive it both from above and below, more greedily than ever. As this new electrification proceeded, I found, by ſeveral trials, that the coheſion became gradually weaker, till, at a certain period, it was totally diſſolved; from which, it began again to be reſtored, and at laſt, when the ſnapping ceaſed, I found it to be as ſtrong as before.

I carried the experiment ſtill farther: I took two complete electrical panes (that is, two glaſs plates, covered each on both ſides with tin-foil), and laying one upon the other, I applied the chain and the wire, and proceeded to electrify. The electrification took place throughout; and I could procure an exploſion from either of them ſingle, or from both together: but however highly they were electrified, I never could perceive the leaſt appearance of coheſion between them. This was agreeable to what I expected. I judged, that, in conſequence of two different kinds of electricity, each of the panes would be charged, on its different ſides, with the different kinds; which, by counteracting one another in the ſame pane, would reduce it to a neutral ſtate of electricity, and by that means prevent the two panes from acting on each other.

It is not here my purpoſe to account for electrical coheſion; yet I cannot but obſerve, that, in this caſe at leaſt, it is obvious, that the coheſion cannot be owing to an *effluence* and *affluence* of one and the ſame electrical fluid: For the two plates being of the ſame ſubſtance, and in every reſpect alike, the effluent current muſt have juſt as great an effect in ſeparating them, as the affluent can have in bringing or keeping them together. The experiment above ſeems to make it evident, that there are two diſtinct kinds of electricity; and the influence of thoſe in making the plates cohere, ſeems naturally to denote, in concurrence with the experiments mentioned in the former part of this paper, two diſtinct and counteracting powers, correſponding with the two different kinds of electricity.

If, upon the whole, the arguments I have brought to prove the exiſtence of two diſtinct powers in electricity, are found to be concluſive, it may, perhaps, be expected of me to ſay ſomething of the nature of thoſe powers. Without entering into any particular theory, or indulging myſelf in looſe conjecture, I ſhall take the liberty to offer a few conſiderations, ſuch as occur to me on this occaſion.

All we know of active powers, extends no farther than as we perceive them to be effects of a power ſtill more general; or as we find them producing effects according to certain laws. I have not been able to trace the powers of electricity farther back, than the obſervations I have given above, have led me. I do not therefore take upon me to determine, whether they conſiſt of the finer parts of matter, conſtituting an active and elaſtic fluid, the elaſticity of that fluid remaining ſtill to be accounted for; or if they are of a ſubſtance yet more ſubtile and active, of which, however, we have hitherto been able to form no diſtinct idea. Whatever other power they may be the immediate effects of, or whatever be the ſecret and imperceptible manner in which they act, the more intereſting object of our inquiry, is to know the laws according to which they act, and how far their operations extend in the material world.

The ſame obſervations that lead us to the diſcovery of any power, if followed out with due attention, may ſerve to inſtruct us in the laws of its action; and if we can attain a ſufficient knowlege of thoſe laws, however ignorant we may be of the peculiar manner in which the power exerts itſelf, we may be, by that means, enabled to trace it through its various operations.

The laws of nature are few and ſimple. It is only from the variety of circumſtances, under which the reſpective powers are exerted, that the phenomena of nature are multiplied. The powers of mechanic motion, thoſe I mean by which bodies act upon one another in impulſe or preſſure, are found to be under the direction but of three general laws; and from thence is deduced a moſt extenſive branch of natural knowlege.

The laws that regulate the powers, by which bodies act at a diſtance upon one another, when we come to be better acquainted with them, may be found to be not more numerous or complex. What appears wonderful to us, is, that bodies ſhould at all be capable of acting upon one another at a diſtance: But are we not equally ignorant of the manner, in which the powers of motion are exerted, when the bodies are in actual congreſs? Daily experience convinces us of the fact in this caſe; and in the other, repeated experiments, and frequent obſervations, leave us little room to doubt, that there are powers, which, when lodged in one body, are capable of being exerted upon another at a diſtance.

The powers of electricity are found to be of this nature. When either of thoſe powers prevails in a body, it exerts its influence, ſo long as it is lodged there, every way around, and, by preſſure or otherwiſe, acts upon another body within the ſphere of its influence. If it meets with no reſiſtance, it enters this other body, and from this begins to act, as it did from the former. In the mean while, the counteracting power prevailing in this other body, the like effects will be produced: and thus theſe two bodies, by means of their correſponding powers, will continue to act upon each other, till their powers be reduced to an equal ballance.

Did electricity conſiſt but of one power, after an experimental inquiry into the laws according to which it acted, we might, upon that principle, be able to account for the phenomena of electricity. But if two diſtinct and counteracting powers prevail, as appears to me to be evident from the preceding experiments and obſervations, in that caſe, it will be impoſſible to give a complete and conſiſtent theory of electricity, but upon the principle of two ſuch powers. Nor will this principle be found, upon due conſideration, to diſagree with the general ſyſtem of nature. It is one of the fundamental laws of nature, that action and re-action are inſeparable and equal. And, when we look around, we find that every power, that is exerted in the material world, meets with a counteracting power, that controls and regulates its effects, ſo as to anſwer the wiſe purpoſes of Providence.

* * *

PATENT OFFICE LIBRARY

LETTER

TO

The REVEREND Dr. BIRCH,

Secretary to the ROYAL SOCIETY,

Concerning the Force of Electrical Coheſion.

SIR,

Read Dec. 20. 1759. I Happened to be at Mr. Symmer's on Saturday the 15th inſtant, when he deſired me to be witneſs to ſome electrical experiments, he was about to make, with ſilk ſtockings, of a particular kind, which he had received for that purpoſe.

The weather was then remarkably favourable for electricity, being clear and dry, with a ſharp froſt, which had continued five or ſix days. The wind was eaſterly, and had been in that quarter for ten days. It was about noon when we made our experiments; the barometer at 30, and Fahrenheit's thermometer at 32.

The ſtockings above-mentioned were wove of carded and ſpun ſilk, and were more ſubſtantial and weighty, than thoſe with which he had made the experiments mentioned in his third paper. One pair was of a deep black, having been twice dyed, in order to improve the colour. Another pair was of the natural colour of the ſilk, of a duſky white; and both new. The pair of black weighed four ounces, eight pennyweight, and four grains; and the white three ounces, eighteen pennyweight, and fifteen grains.

We began with making a few experiments with the thin ſtockings formerly made uſe of; and found the reſult to be much the ſame with what is related by Mr. Symmer in his third paper: that is, we found, that when the white ſtocking was put within the black, or *vice verſâ*, and both highly electrified, taking hold of the one, while a ſcale with weights was put to the other, we could raiſe ſeventeen ounces before the ſtockings ſeparated.

We then repeated one or two of thoſe experiments with ſome little variation of circumſtances. We turned one of the ſtockings inſide out, and put that within the other: the inner or rough ſides of the ſtockings being thus together, by which means they took faſter hold of each other, we now found, that it required the weight of twenty ounces to ſeparate them.

When the ſtockings were ſeparated, and applied externally to each other, they then raiſed the weight of ten ounces *.

---

* Some time after this letter of Dr. Mitchell's had been read in the Society, as I was of opinion, that the thin ſtockings, mentioned above,

We next proceeded to try the force of electrical cohesion, with the ſtockings of a more ſubſtantial make; viz. thoſe I have above deſcribed; and there we found it to be much more conſiderable, as appears by the following experiments.

1° When the white ſtocking was put within the black (without either of them being turned inſide out), ſo that the outſide of the white was contiguous to the inſide of the black, they lifted nine pounds, wanting a few pennyweight. Now, taking the weight of the ſtocking to be one ounce, eighteen pennyweight, and fifteen grains (viz. the half of the weight of the pair as mentioned above), it follows, that,

---

above, had loſt much of their electrical power ſince the beginning of April laſt, when they firſt had been made uſe of in experiments, and that it was owing to the peculiar influence of the weather, that they raiſed as great a weight now as they had done then, I had the black new dyed, and the white waſhed, and afterwards whitened in the fumes of ſulphur. Upon this, I found their force very much increaſed. On the 9th of January, the weather being much in the ſame ſtate as it had been the 15th of the preceding month, the ſtockings, thus prepared, and put one within another, having their rough ſides together, lifted no leſs than three pounds and three ounces before they ſeparated. Dr. Mitchell was likewiſe preſent at this experiment.

How far the circumſtance of ſmoking the white ſtocking in the fumes of ſulphur, might have contributed to increaſe the electrical power, is what I cannot take upon me to ſay. I ſhould think, however, that it does not much contribute to it; for we find, by the experiments in the ſequel of this letter, that the force of coheſion is ſurpriſingly great between the black and the white ſtocking of ſpun ſilk, when electrified: and yet I was aſſured by the hoſier, that the white had never been put into the fumes of ſulphur; and that the colour it had was the natural colour of the ſilk, no other method having been taken to whiten it, than that of ſcouring and waſhing.

that, by the force of its coheſion with the black, it raiſed fifty-five times its own weight.

2°. When the white was turned inſide out, and put within the black, their inner or rough ſides being contiguous, they lifted no leſs than fifteen pounds, one pennyweight and a half, before they ſeparated: So that, in this caſe, the ſingle ſtocking raiſed ninety-two times its own weight †.

3°. When the inner ſtocking was drawn out, and applied to the outſide of the other, they lifted one pound and three quarters; that is, between ten and eleven times the weight of the white ſtocking *.

It

---

† Since that time, I have not been able to raiſe above ten or eleven pounds with theſe ſtockings, even when the weather has been moſt favourable; owing, perhaps, to my having cut off all the ends of threads, and tufts of ſilk, which had been left on the inſide of the ſtockings; which I did with a view of increaſing the coheſion: whereas, when the inner ſides of the ſtockings were put together, thoſe ends of threads, and tufts of ſilk, by joining intimately with thoſe of the different colour, probably contributed much to produce that powerful coheſion.

* In the third of theſe papers I obſerved, that ſtockings electrified, and applied to one another externally, cohered with a force greater or leſs, according to the manner in which they joined in contact with each other. This appears to be the reaſon, why the ſtockings here made uſe of, being much leſs pliable than the thinner kind, do not, in external coheſion, raiſe a weight ſo great in proportion as thoſe do. From thence I fancied, that if the ſtockings of ſpun ſilk ſhould be firſt allowed to come together, and afterwards be preſſed cloſe between one's hands, their coheſion externally with one another would thereby be much improved: Accordingly, upon repeated trials, I found, that the white ſtocking, when thus preſſed to the black in external contact, was capable of raiſing between three and four pounds; that is, about twenty-two times its own weight.

I have

It is not my deſign to draw any concluſions from theſe experiments, and much leſs to determine how far electrical coheſion may ſerve, as a principle, to to account for many remarkable appearances in nature. I relate the experiments I have been witneſs to, by way of ſupplement to Mr. Symmer's third paper; and I conſider the reſult of them, only, as a farther proof of the ſurpriſing degree, to which a power in electricity, which had not before been attended to, may be carried, in even the ſlighteſt ſubſtances, thoſe of white and of black ſilk. I am,

SIR,

Your moſt obedient, humble ſervant,

Kew, December 18, 1759. John Mitchell.

I have taken the liberty to ſubjoin theſe few obſervations, by way of notes, to Dr. Mitchell's letter, as they relate to the ſame ſubject, and contain matter, which has occurred ſince his letter was read in the Society.

February 1ſt, 1760. R. Symmer.

FINIS.

PATENT OFFICE LIBRARY